Research and analysis of modern space heating technologies and management for industrial buildings

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Research and analysis of modern space heating technologies and management for industrial buildings

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Abstract. The paper observes different modern space heating technologies suitable for industrial buildings. Their main working principles and applications are researched related to their energy efficiency. The problems about heating of large scale spaces in industry are observed. A compartment analysis between the technologies is carried out with their advantages and disadvantages.

1. Introduction

The industrial sector represents about 26% of total EU-28 energy consumption in 2012. Although industry is only the third largest end-use sector in the EU after buildings with a share of 40% and transport with 32%, in some countries with more energy-intensive industries, such as Austria, Germany, the Czech Republic or Sweden, the share varies between 30 and 35%. In Finland and Slovakia, industry contributes more than 40% of total energy consumption. [1]

In recent years, the industry has been seeking more and more energy efficient solutions for heating and minimizing production costs. One of its main problems is the winter heating of buildings, halls or workshops where the heat goes out because of numerous factors such as: large spaces, high ceilings, flow formation, constantly opening doors, poor thermal insulation, etc. Known heating systems (radiators, convectors, air conditioners, etc.) heat the room on the convection principle, heat the air, it becomes lighter and rises to the ceiling, where the colder surface of the ceiling cools it, where becomes heavier and moves down again to the floor of the room. This cycle is repeated and causes air circulation, causing unpleasant differences between floor and ceiling air temperatures, as well as the spread of dust, smoke, noise and CO_2 emissions.

The temperature of heated industrial workplaces is important issue when it comes to workers health and safety, but also on productivity. It is considered that workers perform better between 16°C and 24°C, depending on working process.

According to the Chartered Institute of Building Services Engineers, (CIBSE) different working environments require different temperatures. For example:

- Heavy work in factories: 13°C
- Light work in factories: 16°C
- Hospital wards and retail: 18°C
- Offices and dining rooms: 20°C

Other problems that may occur due to bad heating systems and their maintenance are employee bad concentration, dizziness, fainting, or even heat stroke. Apart from the social consequences, usually there are high energy costs and bad environmental footprint because of the use of the wrong heating technologies or lack of proper heater control, poor ventilation and air circulation. [2]

In order to choose the most relevant solution for heating large spaces, the designers should keep up with the modern heating technologies and have the ability to implement them in the best way, based on the building's heating demands. The improvement of existing HVAC technologies, as well as the development of smart building systems and their combination, can contribute in rising the quality of work and working environment, not only in the industry but also where large volumes and open spaces are a complicated test for energy efficient heating like concert halls, sport areas, event centres etc.

2. Heating technologies for industrial spaces

The well known technologies for heating industrial premises, like direct and indirect gas heaters, fan heaters, electrical heaters and boiler systems has few things in common: high energy consumption and convection principle of work, which leads to temperature differences, low heating effect and high consumption costs. In order to make one step closer to energy efficient future, new methodologies with renewable resources and innovative heating technologies should be applied combined with well developed intelligent management systems.

2.1 Heating systems with solar power

Industrial buildings have large and usually flat roof space which is a great opportunity to install solar panels. Industry can significantly reduce their overheads by generating their own electricity from solar energy. Solar heating systems can be applied for heating hot water alone or combined with space heating and can be matched with different type of space heaters. The main components include the collector which collects the solar energy, a thermal storage unit which transports the collected heat to the storage and store it for later use and a heat generator. It is assumed that the solar system is supplementary to the primary heating system, because it is most common to have a solar fraction of less than 50 % of the DHW and space heating demand. The performance is very dependent on especially the size of the solar collectors in relation to the energy consumption. [3]

Solar energy is available at the place, where it can be converted into heat. If it is the same with the auxiliary energy, then it is an autonomous system. Despite that, electricity is always needed for operation of any heating system for the different components such as fans, pumps, compressors of the heat pumps, the automatic control system to operate, thus the solar heating system is not entirely autonomous. In order to be fully autonomous both heat and electricity should be produced on site. For achieving zero energy buildings a well-developed automatic control system should be developed that controls the energy gain and consumption. Their operation depends on the the functions of the system, required temperatures and expected heating load and their adaptation is developed by the consumer heating requirements. [4]

The electricity generated by solar panels first supplies on-site needs, with the grid supplying additional electricity as needed. When the building generates more electricity than it consumes, the electricity is fed back into the grid. It is very effective for administrative buildings, big stores and production factories. There are lots of benefits of solar electricity but the most important one is the carbon free usage — solar electricity is green renewable energy and doesn't release any harmful carbon dioxide or other pollutants.[5]

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2.2 Heat pumps

Heat pump technology can deliver great economic, environmental and energy system benefits worldwide. The idea behind of a compression heat pump is the thermodynamic cycle, which is popular also as refrigeration cycle (Fig. 1). It has 5 components: an evaporator (a "liquid-to-gas" heat exchanger), a compressor, a condenser (a "gas-to-liquid" heat exchanger), an expansion valve, a transfer fluid (refrigerant).

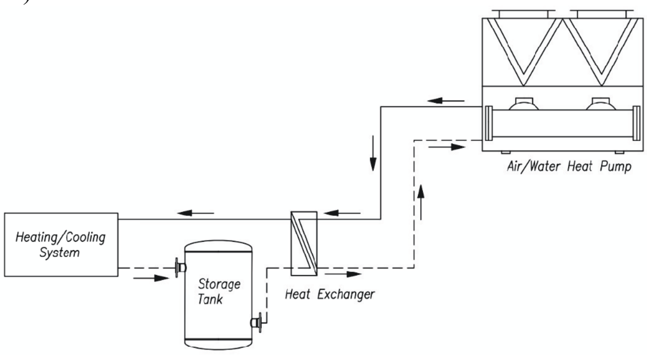

Figure 1. Heat pump working scheme

An electric compression heat pump uses electricity to run the compressor and the pumps; a sorption heat pump uses thermal energy to drive the cycle. But when it counts to the total energy balance, the share of electrical energy needed to drive the cycle is relatively small.

Heat pumps can use renewable energy from air, water or excess energy from industrial processes and infrastructure installations like subway or underground parking. The type of energy used determines the heat pump technology and is also part of the typical naming convention: Air source heat pumps use air as energy source; Geothermal heat pumps use ground energy, which is transferred to a transfer fluid and transported to the heat pump unit; Water source heat pumps use water connected to aquifers, rivers, lakes, sea, and others.

Industrial heat pumps are most often bespoke systems designed to the building's specific needs. The application may be for industrial and production needs, rarely only heating, so it is not preferable choice if it is not included in the production operation. One of the challenges in industrial heat pump design is the selection of components that can operate at higher temperatures on the side of the energy source. [6]

Heat pumps for heating and cooling demand is increasing in most countries. They serve well for cooling in summer peak or heating in winter peak situations, but in very low temperatures(below - 25 C^{o}) they need to be stopped and secondary heating systems should be taken in consideration.

The control of heat pumps is in a similar way as other air-conditioning systems such as electric or gas heating. Usually heat pumps have remote control capabilities for easy operation needs. [7]

2.3 District heating and cooling systems

District Heating and Cooling (DHC) systems increase the overall efficiency of the energy system by recycling heat losses from a different energy conversion processes. It is based on the recovery of heat, that otherwise would be lost, that is delivered for consumption needs of industrial process or building management (Fig. 2). Many renewable sources such as biomass and geothermal energy are difficult to use for other purposes, but in DHC systems they can be efficiently included in the process. The evolution of DHC has three main stages. First, they were using steam as a heat carrier. Until 1970s the systems used pressurised hot water as a heat carrier, with temperatures mostly over 100ºC. Modern systems also use water as the heat carrier below 100ºC, following the requirements for lower and more flexible distribution temperatures, assembly oriented components, and more flexible materials which leads to s environmentally friendly and customer-oriented solution. [8]

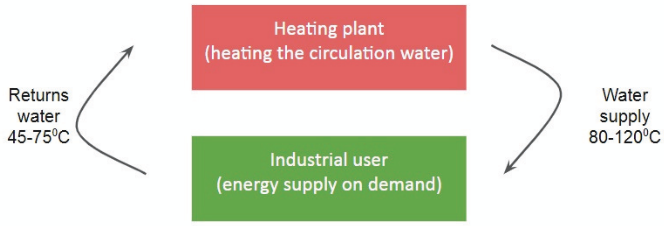

Figure 2. District heating principle

DHC systems are still not very popular in industry heating, but play effective role in emissions reduction and energy savings. They consist of networks of insulated pipes, pumps, energy sources and end users. Heat exchangers transfer heat from a district heating network to a building's own heat and hot water systems, while return water is pumped back to the heating plant. District cooling uses the same principles. Modern DHC can be flexible in terms of source, size and load. Currently they are dominated by fossil fuels such as coal and gas; it can use any fuel including excess heat that is currently being wasted, renewable resources and cogeneration. Each network needs to be developed according to the circumstances and can be adapted to innovation systems like BMS (Building Management Systems) that enable data management relating to temperatures, flows, pressure and leak detection. The repairmen of existing network for construction and expansion of district energy networks and integrating the use of a large share of renewable power, serving as thermal storage can be a major advantage for future smart energy systems. Smart DHC network management would help control the demand and system temperatures, which would reduce heat loss and accordingly energy demand. Smart optimisation and control technologies as well as IoT would also enable better cooperation with service providers and equipment manufacturers. [9]

2.4 Infrared heating

One of the latest technologies entering the market for heating appliances is infrared (radiant) heating. It uses infrared radiation, radiating heat, which concentrates in the areas where it is needed and used, and does not spread throughout the room ort flow through enclosing structures. When the rays reach the earth's surface or other object, they heat up, and this heat warms the air around. Due to the pronounced thermal effect of infrared rays, they are successfully used for heating. This solution is extremely economical compared to mass conventional heating appliances and is considered to be energy efficient thanks to the conversion of up to 98% of electricity into infrared radiation. Due to the fact that air is not used as a heat transporter, heat losses are significantly reduced, since air is a good insulator and not a heat accumulator. It remains at almost the same temperature throughout the entire height of the room. Manufacturers of these types of heating systems claim that energy savings can be as high as 70% when the appliances are properly installed and operated. The best efficiency from heating with infrared panels is registered when they are installed in the ceiling of the respective room, because it has full coverage to the whole room, warms the floor from there it warms the air from the bottom up. After ventilation of a room heated by infrared radiators, the return to the desired room temperature becomes much faster due to the fact that all surfaces in the room are warm. Due to the fact that the surface of objects and bodies in the room is about 1 ° C higher than the air temperature in the room, the possibility of condensation and mould formation in the room is drastically reduced.
With series of experiments in industrial space with thermal camera, was proven the efficiency of the infrared heating comparing to a convection heater. The thermal camera visualized that, although with a lower power, the temperature reached in the radiant heater corpus exceeds three times that in the corpus of the convection heater (Fig. 3). The warm air from the stove was scattered throughout the

room and no significant warming effect was felt during the experiment. The radiant heater heated the area constantly from the start, with warming effect right from the beginning. [10]

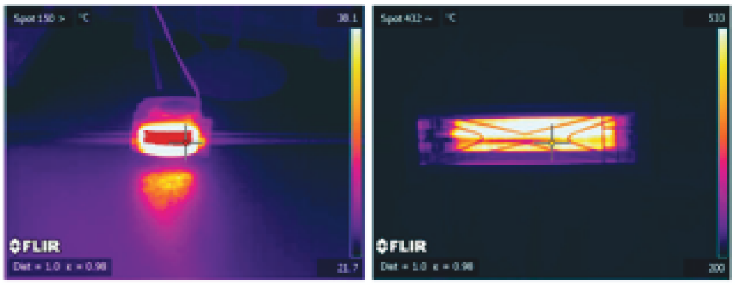

Figure 3. Thermal image of infrared heater and convection heater

Infrared heating systems are very applicable for developing intelligent heating system as part of an overall BMS. Because of coactions between temperature sensors and the control of heating systems, all areas throughout the space or different zones can be maintained with the appropriate temperature even remotely. This helps for several of outside factors such as outside temperature, humidity, natural heat to be taken into consideration in order to reduce energy consumption. Also infrared heating systems can interact flexibly to individual user behaviour to provide safety and comfort.

3. Comparative analysis

In order to achieve the most suitable solution for increasing the energy efficiency, designers and engineers, have to be aware of every method positive and negative sides. The main advantages and disadvantages of the reviewed heating possibilities are listed below in Table 1.

Table 1. Types of heating advantages and disadvantages

	Advantages	Disadvantages
Heating systems with solar power	Uses renewable resources;	High initial cost;
	Suitable for the big scale roofs in industrial buildings;	Uses the roof space;
	Can use the build in heating/cooling system;	Depends on the availability of solar radiation at the specific geographic location;
	No carbon footprint;	Needs energy storage equipment;
	Return of investment.	Needs regular maintenance.

Heat pumps	Uses renewable energy; Effective; Great development opportunities.	Uses electricity Depends on the geographical location; High initial costs; Doesn’t work in low temperatures; Complicated design.
District heating and cooling	Easy to install; Reduced maintenance costs; Use small space; Safe; Energy efficiency is improved both on the production and distribution sides. reduced distribution losses; System flexibility; Works with BMS;	Suffers heat losses to the ground; Requires large upfront capital investment; Only available for buildings in areas where a district heat network is available.
Infrared heating	Energy efficient; Heats large and high spaces; Starts to heat up from the moment of switching on; It does not pollute and emit no harmful substances; Noiseless; Easy maintenance; Option for zoned heating; Ability to use remote control, thermostat and smart systems.	Uses electricity; If not installed in suitable height it can cause unpleasant warming effect.

As a future steps, based on the overview of the different heating technologies, a base model for increasing the energy efficiency in industrial buildings will be developed using infrared heating. The model will be based on the heating specifics and building's consumer needs. It will implement modern smart technologies and IoT for maximum results in energy efficient heating.

4. Conclusion

With the new directives for tightening the energy consumption worldwide, the demand of new, energy efficient heating systems increases. This topic is extremely relevant to industrial buildings, characterized by large spaces, wide openings, zoned working processes and special production demands. Most of the systems require large upfront investment to build, or are not suitable for already build premises. Infrared heating has a lot of advantages for these industrial needs and becomes a preferable solution when it comes to easy maintenance, bespoke installation, safe working and lack of heat loss. The ability to integrated it with management systems and IoT helps even more in increasing the energy efficiency, reducing the heating costs and harmful emissions and increasing the comfort of the employees on-site.

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